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heretics; if burning *be, as it most assuredly is*, a most effectual mode of suppressing opinions, why should we not burn? If the relation in which government ought to stand to the people *be*, as Mr. Gladstone tells us, a paternal relation, we are irresistibly led to the conclusion that persecution is justifiable." Just below he says: "If a boy *plays* truant at church-time, a task is set him." Again, we find *if it be true* and *if experience shows*, both in the same paragraph. It might be thought that Macaulay was unwilling to use any other subjunctive than *be*, which indeed is the one that most frequently occurs in modern English. Mr. Gladstone writes (*Studies on Homer*, I. p. 18), "If Homer *is* not fully studied in our Universities," and in the next page, "If my estimate of those purposes *be* correct." Again (p. 39), "If it *be* contended," and (p. 80) "If such there *has* been."

These instances are quoted here not by way of criticism, but simply to show the utter want of any principle in English on the subject. It is for scholars to determine whether it is desirable to retain the subjunctive in English; and whether, if it is to be retained, it is not better to restrict its use to conditions referring to the future, or at least not to allow it to be used beyond the limits which the classical languages so clearly define. The present laxity of usage in respect to it is certainly no honor to our language.

Five hundred and forty-third Meeting.

December 13, 1864. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters relative to exchanges.

Mr. Ferrel read the following paper.

Note on the Influence of the Tides in causing an Apparent Secular Acceleration of the Moon's Mean Motion.

As the unit of time depends upon the time of the earth's rotation upon its axis, any slight secular change in the time of its rotation, must cause an apparent secular acceleration or retardation of the moon's mean motion. There are two circumstances which may affect the time of the earth's rotation, first, the effect of the attractions of the sun and moon upon the tidal wave retarded by friction, secondly, a gradual decrease of the earth's volume from a loss of heat.

If we conceive the whole surface of the earth to be covered with water, and consider only one section of it perpendicular to the earth's axis, as that of the equator, the effect of the moon is to cause the outline of the fluid to assume the form of an ellipse; and if the tidal wave moved without friction the vertices of this ellipse would be either exactly in the plane of the meridian on which the moon is vertical, or 90° from it, the position depending mainly upon the latitude of the place and the depth of the ocean. In either of these cases the attraction of the moon could not affect the time of the earth's rotation. But as the fluid cannot move over the surface of the nucleus without friction, the position of the vertices of the ellipse, or tidal wave, is a little displaced from the position which they would have without friction, in the former case a little to the east, and in the latter a little to the west. If the resultant of the moon's attraction upon the earth and the counteracting centrifugal force be resolved into radial and tangential forces perpendicular to the planes of the meridians, the latter only can have any tendency to affect the earth's rotation. In the first quadrant east of the meridian upon which the moon is vertical, and its opposite, these tangential forces are towards the west, but in the other two quadrants toward the east. Neglecting quantities of a very small order, these forces in the different quadrants are exactly equal, and hence when the quantity of matter in these quadrants is the same, they can have no tendency to affect the earth's rotation. But we have seen that friction tends to throw the greater part of the tidal wave into the quadrants in which the tangential forces are toward the west. This is also the case when the tide is produced by an oscillatory or rocking motion of the fluid east and west, as in the Atlantic Ocean. Hence there is a preponderance of force toward the west, which causes a slight westward motion of the water, and this motion, by means of friction, transfers this force to the nucleus.

In the third volume of Gould's Astronomical Journal I have shown, upon the hypothesis that the outline of the whole tidal wave over the surface of the earth assumes the form of a prolate spheroid, having its vertices displaced 30° by friction, and that the height of the wave above low water is two feet at the equator, that the rotatory motion of the earth at the equator would, by the joint effect of the moon and sun, be retarded about forty-four miles in a century. As the moon moves about 84″ of arc in its orbit while the earth at the equator moves forty-four miles, the moon's motion from that cause would be apparently accelerated that amount in a century. But as the observed secular acceleration of the moon as determined from the records of ancient eclipses, is only about 11″ per century, and this amount of acceleration seemed, at that time, to be almost exactly accounted for by the real acceleration caused by the secular change in the eccentricity of the earth's orbit, as determined by Laplace, so that he inferred that the length of the day had not changed $\frac{1}{400}$ of a centesimal second since the time of Hipparchus, it was inferred in that paper that, if tidal action had any sensible effect, it must be counteracted by a corresponding contraction of the earth's volume from a gradual loss of heat.

Mayer, in his interesting paper on Celestial Dynamics, has also shown that the attraction of the moon upon the tides retarded by friction, tends to increase the length of the day. He has not, however, attempted to determine the amount of effect produced from any assumed form and position of the tidal wave or aqueous spheroid, but assumes that the retarding pressure must be at least one thousand millions of kilogrammes, and upon this hypothesis he determines that the length of the day would have increased $\frac{1}{16}$ of a second in the last twenty-five hundred years, if the volume of the earth had not changed, and that, if the length of the day has not changed, the radius of the earth must have diminished 4½ metres in the same time. Although Mayer's paper was originally published several years before mine, yet as it has only quite recently been brought before English readers by means of a translation published in the London, Edinburgh, and Dublin Philosophical Magazine, and also in Silliman's Journal, it was entirely unknown to me at the time of the publication of my paper.

At the time of the original publication of Mayer's paper, and also at the time of the publication of my own, Laplace's result of about 11″ per century, for the amount of acceleration of the moon's mean motion arising from a secular change of the eccentricity of the earth's orbit, was supposed to be correct, but since that time, it is known, Delaunay and Adams, and also quite recently, Mr. Cayley, by separate and independent investigations, have all obtained less than 6″ for the amount of secular acceleration per century, and it is with reference to its bearing upon this new determination that I especially desired to bring forward the subject at this time. This determination, compared with the most reliable determination of the acceleration deduced from the discussion of the recorded observations of ancient eclipses, leaves about 6″ to be accounted for by tidal action, or some other *unknown* cause. Although we cannot determine the exact amount of effect arising from tidal action on account of the uncertainty of the data upon which the computations are based, yet it may be shown that it requires no extravagant and unreasonable hypothesis with regard to the magnitude of the tidal wave, and its retardation by friction, to produce an apparent secular acceleration of 6″, after making due allowance of the effect of tidal action for counteracting the effect arising from any probable amount of contraction of the earth's volume. If upon the hypothesis of a tidal wave two feet in height, and displaced 30° by friction, the effect of tidal action is to cause an apparent secular acceleration of 84″, then, since the effect is as the sine of double the angle of displacement, an acceleration of 6″ would be obtained from a wave of the same height displaced only about 2°, that is, retarded only about eight minutes, by friction. This is upon the hypothesis of no contraction of the earth's volume. According to the investigations of Fourier the loss of heat sustained by the earth by conduction, in a century, would only be sufficient to cause a diminution of the earth's radius to the amount of about seven millimetres, (nearly one third of an inch) the effect of which upon the earth's rotation would be counteracted by an additional retardation by friction of the tidal wave of only about two minutes. The retarding pressure assumed by Mayer corresponds with the effect of a tidal wave two feet high delayed about 1¼ hours by friction, but from this assumption he obtains a result which is twenty-six times too great for Fourier's theory of the loss of heat sustained by the earth. But he thinks that the loss of heat by simple conduction taken into account in Fourier's investigations, may be but a small part of the whole amount, and enumerates several other ways in which the earth loses heat. Although the loss of heat may be considerably greater than that which would result from Fourier's theory, yet I think the whole amount of loss cannot be so great as to require any unreasonable amount of retardation of the tidal wave by friction, in order that the effect may be great enough to counteract the effect of the contraction of the earth's volume, and also to retard the time of the earth's rotation enough to cause an apparent secular acceleration of 6″ per century in the moon's mean motion, and that the hypothesis in my paper of a displacement of 30°, or retardation of two hours, and also Mayer's hypothesis of the amount of tidal pressure, which corresponds to a retardation of about 1¼ hours, are both much too great to be reasonable hypotheses, or to be necessary to account for the balance of the moon's secular acceleration over and above the late determination. We have seen that the hypothesis of a retardation of the tidal wave by friction of only ten minutes is sufficient, according to Fourier's theory, of the loss of heat, and if we suppose the loss to be somewhat greater than this theory requires, it is only necessary to make the hypothesis a very little greater. If 6″ of the moon's secular acceleration is due to tidal action, then the length of the day has increased about $\frac{1}{140}$ of a second in the last twenty-five hundred years. If the effect of tidal action is insensible, and the late determination of the moon's secular acceleration from theory be received, then we have no way of accounting for the remaining 6″, and besides we cannot allow that the earth's volume has contracted as much as even Fourier's theory requires. The main point at which we have arrived is, that tidal action is adequate to account for 6″ of secular acceleration upon a very reasonable and probable hypothesis with regard to the magnitude and retardation of the tidal wave by friction, after making due allowance of the effect for counteracting the effect of a probable contraction of the earth's volume, and that we therefore have no just reason to reject the late determination of secular acceleration arising from a change of the eccentricity of the earth's orbit, because it does not cover the whole amount determined from the observations of ancient eclipses.

Professor Whitney read a paper on the progress of the Geological Survey of California, and presented to the Academy a volume of his report on the Paleontology of that State.

On the motion of Dr. H. R. Storer a committee was appointed, consisting of Professor Rogers, Dr. A. A. Gould, and Professor Agassiz, to consider what action the Academy should take toward promoting the Geological Survey of California and the adjacent territories.

Five hundred and forty-fourth Meeting.

January 10, 1865. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters relative to exchanges; also a communication from Mr. Otto Struve of the Observatory at Pulkova, announcing the decease of the eminent astronomer his father.